Advances in Coastal Structure Design

Edited by Ram K. Mohan, Orville Magoon, and Mark Pirrello

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ADVANCES IN COASTAL STRUCTURE DESIGN

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Preface

Is there anyone who can watch without fascination the struggle for supremacy between sea and land? The sea attacks relentlessly, marshalling the force of its powerful waves against the land's strongest points. It collects the energy of distant winds and transports it across thousands of miles of open ocean as quietly rolling swell. On nearing shore this calm disguise is suddenly cast off, and the waves rise up in angry breakers, hurling themselves against the land in final furious assault. Turbulent water, green and white, is flung against the sea cliffs and forced in the cracks between the rocks to dislodge them. When the pieces fall, the churning water grinds them against each other to form sand; the sand already on the beach melts away before the onslaught. (Willard Bascom, *Waves and Beaches*, Prologue)

Much debate goes on these days about the tools and techniques used to analyze coastal processes and design engineering solutions to them. In this issue, we present a compendium of papers addressing the state-of-the-art advances in Coastal Structure Design. The internationally renowned authors present uniquely interesting technical updates on this topic. In the first chapter, *The Coastal Structure Debate - Public & Policy Aspects*, Dr. James Houston presents the multiple viewpoints and policies affecting the ever-continuing, ever-evolving debate on soft versus hard engineering along our shorelines. Krystian Pilarczyk follows with a global perspective surrounding the policy, design, construction and monitoring of coastal structures in his chapter, *International Perspectives on Coastal Structure Uses*. In his chapter on *Geotechnical Considerations for Coastal Structure Design*, Dr. Donald Treadwell demonstrates how a good knowledge of multi-disciplinary areas of geotechnical, geologic, and seismic conditions are essential to successful planning and design of coastal structures.

Modeling is always a key aspect of coastal structure design, since one is always challenged by the "mysterious" nature of the ocean. Information about this unique area is shared with us by Dr. Nobuhisa Kobayashi (*Numerical Modeling as a Design Tool for Coastal Structures*), Dr. Steven Hughes (*Physical Modeling Considerations for Coastal Structures*), and Dr. Donald Ward et al., (*Selection of a Design Wave Height for Coastal Projects*). William Baird presents an interesting overview of breakwater design and construction since the 18th Century in his chapter, *Historical Overview of Rubble Mound Structure Design & Construction*. The advances in structural design aspects are covered by Dr. Jeffrey Melby (*Advances in Breakwater and Revetment Design*), who presents a discussion on "performance-based design," and Dr. Kevin Bodge (*Design Aspects of Groins and Jetties*), who presents empirical relationships. Finally, Dr. Edge et al. bring a nice closure to the discussion in their chapter, *Application of Coastal Engineering in Coastal Zone Management*, demonstrating how sand, vegetation, cobbles, and small structures can be effectively utilized to provide coastal protection.

I would like to thank ASCE's COPRI Board for their support of this publication, specifically the committees on "Coastal Practice," "Ocean Engineering," and "Rubble Mound Structures" for their interest in being associated with the production of this book. Finally, I thank the co-editors, Orville Magoon and Mark Pirrello, for their support with this publication.

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THE COASTAL STRUCTURE DEBATE - PUBLIC & POLICY ASPECTS

James R. Houston[1], M.ASCE

Abstract: Coastal structures have been used since antiquity to reduce navigation-channel shoaling and provide protection against wave action in harbors. For example, Herodotus in 440 BC described jetties built along the coast to prevent a navigation channel from shoaling. As sea commerce increased, harbors using breakwaters and jetties were constructed throughout the world. Major cities in the United States were built around ports because of the importance of maritime trade. Navigation's importance in the United States is seen in the "Commerce Clause" of the Constitution that grants the federal government significant rights to regulate commerce including vesting it with navigation servitude that imposes a dominant easement on navigable waters and is used to justify nonpayment of compensation to those who claim their properties have been damaged by government navigation projects. Coastal structures did not become controversial until the latter half of the 20th Century when there was a significant migration of people to United States coasts. Coastal structures are now a center of controversy, and policy continues to evolve as a result of intense public debate. This chapter discusses how the coastal-structure debate in the United States came to be and how policies are evolving to handle issues concerning the interactions of structures with shorelines.

INTRODUCTION

Coastal Navigation Structures

Coastal structures have been used since antiquity to reduce navigation-channel shoaling and provide protection against wave action in harbors. For example, Herodotus in 440 BC described jetties built along the coast to prevent shoaling of a navigation channel (Herodotus 440 BC). Procopius, in describing the Emperor Justinian, noted,

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"And he threw much money into the sea in the form of moles, as if to master the eternal roaring of the breakers. For he jealously hurled stone breakwaters far out from the mainland against the onset of the sea, as if by the power of wealth he could outmatch the might of ocean."(Atwater 1927). In 46 AD, Claudius built the harbor of Portus that was enclosed by two caisson jetties, each more than 700-meters long, and required removal of four million cubic meters of sand to produce five to six meter water depths (Lanciani 1898). Herod the Great, from 21 to 10 BC, built the completely man-made harbor complex of Sebastos at the city of Caesarea Maritima halfway between what is now Tel Aviv and Haifa, Israel. Roman engineers made extensive use of hydraulic concrete made with pozzolana to construct breakwaters enclosing an area of 200,000 square meters. They built large floating caissons partially filled with concrete that were barged to pre-designated sites and sunk in place by pouring additional concrete. These caissons were the foundations for a wall built to shield the harbor from waves (Hooper Virtual Paleontological Museum 1996). The famous historian Josephus Favius in his history between 75 and 79 AD noted that Herod the Great, "... had blocks of stone let down into twenty fathoms of water, most of them measuring fifty feet in length by nine in depth and ten in breadth, some being even larger. Upon the submarine foundation thus laid he constructed above the surface a mole two hundred feet broad; of which one hundred were built out to break the surge, whence this portion was called the breakwater, while the remainder supported a stone wall encircling the harbour." (Hooper Virtual Paleontological Museum 1996.

As sea commerce increased, harbors using breakwaters and jetties were constructed throughout the world. Imperial Spain built harbors in Spain and throughout the New World. The sun did not set on a British Empire that depended on water transport for commerce and sent British engineers to the far corners of the world to build harbors. A country's prosperity and military might became synonymous with its merchant and naval fleet. Coastal structures such as jetties and breakwaters were critical infrastructure that kept navigation channels open and provided safe anchorage.

Seawalls and Shore Protection Structures

The Frisians, who first settled the Netherlands over 2000 years ago, built the first dikes (seawalls) to hold back the sea. The Dutch have continued a 2000-year tradition to reclaim land from the North Sea and then to hold back its waters. In 1287, the dikes failed massively, and water flooded the country. The Dutch rolled up their sleeves and created the Zuiderzee (South Sea) over former farmland. For the next few centuries, the Dutch worked to slowly push back the water of the Zuiderzee, building dikes and reclaiming land. Once dikes were built, canals and pumps were used to drain the land and to keep it dry. From the 1200's, windmills had been used to pump excess water off the soil. Although today most of the windmills have been replaced with electricity- and diesel-driven pumps, windmills are still the national image of the Netherlands. Storms and floods of 1916 and 1953 provided the impetus for the Dutch to start major projects to reclaim the Zuiderzee and later the fresh water Ijsselmeer. The reclaimed land created the new province of Flevoland. The American Society of Civil Engineers named the collective protective works of the Netherlands as one of the Seven Wonders of the Modern World. Sixty percent of the population of the Netherlands now lives below sea level as a result of the flood-protection works (Mining Company 2000).

The seawall at Galveston, Texas, was the earliest example of a large seawall built in the United States. About 6,000 people were killed by a hurricane at the turn of the century in Galveston, and as a result, Galveston Island was raised and a major protective seawall built (Wiegel 1991). The seawall has virtually eliminated loss of life in Galveston for a century including withstanding a hurricane in 1915 even larger than the hurricane of 1900 with little loss of life or damage to development.

Americans Go to the Shore

Today living on the shore is the norm, but living near beaches in America is a 20th century phenomenon. Beach areas were typically near salt marshes making mosquitoes a plague of coastal regions. There were few roads going to beaches and, therefore, little infrastructure to support coastal communities. Communities sometimes had recreation outings with families in horse-drawn wagons carrying picnic food to spend the day or weekend getting to the beach and returning (Oldbridge Waterfront 2001). But few lived on beaches.

In much of America, beaches did not become a vacation destination until the mid-1800's and the advent of railroad connections to coastal areas. For example, in 1854 the first public railroad connection was opened between Camden and Atlantic City, New Jersey. Atlantic City flourished and by the turn of the century was the queen of resorts on the east coast (Atlantic City 2001). The advent of the automobile in the 20th century and the resulting construction of roads made the beach a drawing card for vacationers.

In the second half of the 20th century, beaches started becoming draws for people not just to vacation but also to live. Americans became increasingly comfortable with long automobile commutes to work, allowing them to live in beach areas. Retirement began to mean life in a house or condominium in coastal Florida. The populations of coastal states in the west and south skyrocketed. By the end of the 20th century, three-quarters of the population of the United States lived within 80 kilometers of the coast.

The Debate

Coastal structures have become controversial in the latter half of the 20th Century after a significant migration of people to United States coasts. Jetties that prevent sediment from entering navigation channels are charged with interrupting the flow of sediment along the coast and causing shoreline erosion. Seawalls constructed to protect infrastructure from storms are charged with causing beach loss. Groins and other coastal structures built to protect coastal reaches are noted to inhibit longshore sediment transport and consequently cause downdrift erosion. Coastal structures are now a center of controversy, and policy continues to evolve as a result of public debate.

NAVIGATION STRUCTURES AND THE SHORE

U.S. Policies Governing Navigation

The United States has a rich maritime history with its major cities built around ports. From the mid-17th century, ports were America's lifeline to world communication and commerce. New England whaling ships sailed the oceans for whale oil that powered the nation's lamps with over 700 whaling ships sailing from over 20 ports from Maine to New Jersey (New Bedford Whaling Museum 2001). Southern plantations depended on ships to carry cotton to Europe in exchange for manufactured goods.

The importance of commerce to a fledgling nation is reflected in the "Commerce Clause" of the U.S. Constitution. Among other things, this Clause granted the federal government significant rights to regulate commerce including vesting it with navigation servitude that protects the public interest in navigation. Navigation servitude imposes a dominant easement on navigable waters and beds. One of its primary functions is to justify nonpayment of compensation to private persons who claim their property interests have been damaged or destroyed by government navigation projects. Courts have generally held that, under navigation servitude, claims of damages arising from federal navigation projects are not compensable.

The federal government authorized the first navigation-channel improvement project in 1789. The U.S. Army Corps of Engineers traces its history to 1775, and the General Survey Act of 1824 established it as the federal agency responsible for the navigation system, since the Nation's engineers were military engineers (American Association of Port Authorities 2001). Section 10 of the River and Harbor Act of 1899 required authorization from the Secretary of the Army, acting through the Corps of Engineers, for the construction of structures in navigable waters or construction work outside navigable waters if the structure affected the course, location, or condition of a water body. The law applied to dredging or disposal of dredged materials and any other modification of navigable water. It applied to all structures, from the smallest floating dock to the largest commercial undertaking, including wharfs, dolphins, weirs, breakwaters, jetties, groins, bank protection (e.g., riprap, revetment, bulkhead), mooring structures such as pilings, intake or outfall pipes, permanently moored floating vessels, tunnels, artificial canals, boat ramps, aids to navigation, and other permanent, or semi-permanent obstacles or obstructions (Wilmington District 2001).

With the realization that navigation structures can alter patterns of erosion and deposition along shorelines, Section 111 of the River and Harbor Act of 1968 provided the Corps of Engineers authority to develop projects for the prevention or mitigation of damages caused by federal navigation projects. The authority did not extend to projects that prevent or mitigate shore damage caused by riverbank erosion, vessel-generated wave erosion, or shore damage caused by non-federal navigation projects. It was not intended to restore shorelines to historic dimensions, but only to reduce erosion to the level that would have existed without the construction of a federal navigation project. A non-federal partner, which could be a state or local government or tribal agency, was required to cost share using a cost-sharing formula based on the cost share of the navigation project that produced the damages (Philadelphia District 2001). Congress directed the cost of individual projects be capped (recently raised to $5 million) unless authorized by specific Congressional action.

The Problem

The National Research Council (1990) notes that natural tidal channels through inlets or other entrances can have substantial capacity to modify sediment transport and